Development of the Concept of Middleness in Children: Response Time and Complexity

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Cox, R. & Williams, K. (1993). Development of the concept of middleness in children: Response timing and complexity. Perceptual and Motor Skills, 77, 1275-1281.

Summary:
24 boys and 16 girls ages 4 through 7 years were tested on an apparatus that required children to select the middle of 3, 5, 7, or 9 stimulus lights when arranged adjacent to one another and when spaced symmetrically or asymmetrically. Analysis indicated response time decreased with age and increased as a function of the number of stimulus lights in the task. Time to respond to asymmetrical arrangements was greater than for problems whose stimuli were arranged symmetrically.

Article:
Middleness as a relational and developmental concept has been defined in terms of magnitude (color, density, size, etc.) by one group of investigators and in terms of position by another. Stevenson and Bitterman (1955), Graham, Jackson, bong, and Welch (1944), and Munn (1938) all used groups of three objects of different sizes in teaching the concept of middle-sizedness to children. Tsai and Chien (1968) reported that difficulty in determining "the middle" in relation to various concepts (length, height, size, position, color, and density) was contingent upon children's developmental level. In contrast, another group of investigators studied middleness as defined by intermediate position using chimpanzees (Rohles & Devine, 1966, 1967; Spence, 1939; Yerkes, 1934) and children (Rohles, 1971) as subjects.

The subject for the investigations by Rohles and Devine (1966, 1967) was a chimpanzee tested at 5.5 and 6.5 years of age. The animal was trained to seek out (for a reward) the middle object in an array of 3, 5, 7, 9, 11, 13, 15, and 17 objects displayed symmetrically or asymmetrically. An asymmetric array was one in which an interpolated space was strategically placed in the array. Analysis showed that errors in selecting the middle object increased as the magnitude of asymmetry and number of objects in the array increased. The authors concluded that a chimpanzee is capable of developing the concept of middleness but were unable to explain how chimpanzees make complex discriminations of middleness.

Building upon previous animal studies, Rohles (1971) extended his research to include the development of middleness in children. Testing children 3 through 12 years of age, Rohles manipulated factors hypothesized to influence task complexity, namely, number of objects (blocks) in an array, symmetry of array, and color of middle block. Rohles concluded that the ability to solve a middleness problem begins to emerge at 3 years of age. He theorized that children used different strategies to solve simple as opposed to complex middleness problems. For example, Rohles (1971) suggested that selecting the middle object from an array of 3, 5, or 7 blocks was considered to be primarily a "perceptual-motor" problem. Conversely, selecting the middle object from an array of 9, 11, or 13 blocks involved counting, reasoning, and more advanced number skills. Evidence for these conclusions was based upon the longer time required to solve the more complex problems, although response time was not recorded or measured.

Gibson's theory of direct perception (1977) may be useful for explaining differences in identification of middleness by young children. Gibson and others (Michaels & Carello, 1981) suggested that information in the environment is directly perceived rather than being submitted to cognitive transformational operations (like counting or advanced number skills, e.g., Siegler & Crowley, 1991). Gibson hypothesized that information was specified by ambient light. That is, information is directly specified in the environment, making translational processes unnecessary. Experience has been shown to be important in the accuracy of translating perceptions to action, however (Ulrich, Thelen, & Niles, 1990). It seems likely the young children Rohles (1971) tested had sufficient experience with small numbers of objects to be able to perceive directly and select the middle point of the array. Conversely, nine objects may have surpassed some experience-based perceptual break point. It is possible that they resorted to using more familiar counting or other strategies to solve these more complex problems (Siegler & Crowley, 1991). It is also possible that the same processes (like counting) were used, regardless of the length of the array. Longer arrays simply required additional processing time. These notions are purely speculative, however, since Rohles (1971) did not test any explicitly stated theory.

The purpose of the present investigation was to extend early research by Rohles (1971) and Rohles and Devine (1966, 1967) to include response time. Rohles (1971) reasoned that increased response time was evidence of a complex strategy used to solve a difficult middleness problem. Consequently, the specific purpose of this investigation was to investigate by age and gender differences in response time for a series of variables hypothesized to increase task complexity, i.e., age, gender, number of stimuli in array, position of array, and symmetry of array.

TABLE 1

TWENTY-FOUR MIDDLENESS PROBLEMS AS PRESENTED TO CHILDREN (REPEATED THREE TIMES)

	Lights in Middleness Light Display: p																			
	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1								X	X		X	X	X							
2	X		X	X																
3									X	X	X									
4	X	X	X	X	X	X	X													
5									X	X		X								
6							X	X		X	X	X	X	X						
7																X	X	X	X	X
8	X	X	X																	
9											X	X	X	X	X	X	X		X	X
10									X	X	X	X	X							
11	X	X	X	X	X	X	X	X	X											
12															X	X		X	X	X
13	X	X		X	X	X	X	X	X	X										
14						X	X	X	X	X	X	X		X	X					
15							X	X	X	X	X	X	X							
16	X	X	X	X	X		X	X												
17												X	X	X	X	X	X	X	X	X
18														X	X	X	X	X	X	X
19							X	X	X	X	X	X	X	X	X					
20													X	X		X	X	X	X	X
21																		X	X	X
22	X	X	X	X	X															
23																	X	X		X
24	X	X	X		X	X														

METHOD

Subjects

Subjects were 24 boys and 16 girls 4 through 7 years of age. Signed consent and cooperation were obtained from parents. Confidentiality of results was assured.

Equipment

The testing apparatus consisted of a series of 20 light-emitting diodes displayed horizontally. These lights were mounted on a display board in a curve to subtend an angle of 15°. The display board was 18 cm high, 96 cm wide, and mounted perpendicular to a horizontal base board. The lights were mounted 5 cm from each other and 12 cm above the base board. A response key was situated 4 cm below each light. The lights and response keys were linked to a Zenith personal computer which controlled the order and frequency of light stimuli. Response times associated with each response (correct and incorrect) were collected and stored by computer.

Task

As illustrated in Table 1, the problems used in the study consisted of 24 separate combinations of lights repeated, as a block, three times (72 problems). Arrays were varied by changing the number of stimuli (3, *5*, 7, or 9 lights), their relative positions on the display board (left, center, or right of the midline), and whether an unlighted LED was interpolated between the relevant stimuli (asymmetrical array). The order of the 24 problems was random. For the test, a child was seated in front of the apparatus at its center (between lights 10 and 11). An adjustable chair was used so that a child; could be seated with the lights at eye level. The child was asked to place then preferred or "favorite" hand on a black marker, situated in front of and between lights 10 and 11. Each was asked to wait for the warning light, following which each was to choose the middle light as quickly as possible and to depress the corresponding button. All children were initially given three practice trials to ensure understanding of the task. Additional practice was given if necessary.

Each problem in the sequence was preceded by a 1-sec. red warning light followed by a 1-sec. delay interval after the warning light went off. Each problem remained illuminated until the correct response key was depressed. If the correct button was depressed, the array went out. If not, the lights remained on, giving the subject another opportunity to respond. A default time of 10 sec. was used. After this time, the array automatically went out and the next problem was given, preceded by the warning light.

Experimental Design and Analysis of Data

Data were analyzed using analysis of variance general linear models procedures (SAS Institute, 1985). *Post hoc* comparisons were made using the Tukey procedure as outlined by Keppel (1982). An alpha level of .05 was adopted for all tests of significance.

Five independent variables were manipulated. Two of the independent variables were grouping variables (age and gender), and the remaining three were repeated measures, Ten subjects were tested at each age (4, 5, 6, and 7 years). Each age category included six boys and four girls. Thus, the design was balanced relative to age but not gender. The repeated factors were (a) number of lights in the array (3, 5, 7, or 9), (b) position of the array on the display panel (left, center, or right), and (c) interpolated space in the array (yes or no). The dependent variable for all variance analyses was total response time from onset of light display to depression of the correct button (middle button). If the first attempt was correct, total response time would be based on one response. If the first attempt was incorrect but the second correct, total response time would be the sum of the first and second response times for that trial. This could continue with multiple incorrect responses until the default of 10 sec. was reached.

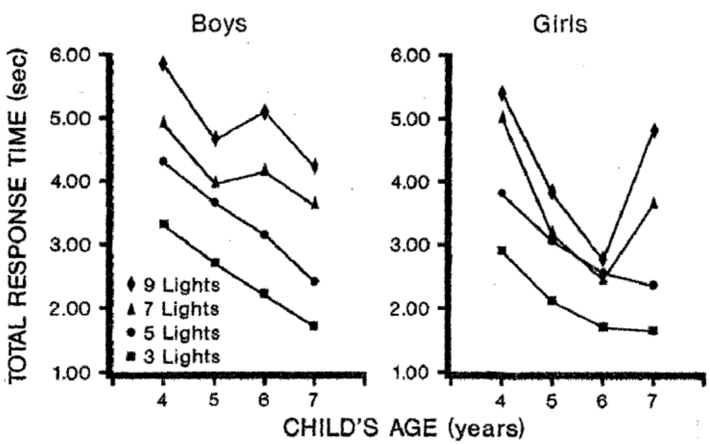

FIG. 1. ***Illustration showing the nature of the second-order interaction among the independent variables of gender, age, and number of lights in array***

RESULTS

Analyses of variance, involving all five independent variables, resulted in significant main effects for age ($p <$ .004), number of lights in array ($p < .0001$), and interpolated space in array ($p < .0001$). Significant first-order interactions included age and number of lights ($p < .002$), number of lights and position of array ($p < .0001$), and position and interpolated space ($p \leq .003$).cat The only other significant effect was the second-order interaction between age, gender, and number of lights ($p = .003$).

The nature of the second-order interaction between age, gender, and number of lights in array is illustrated in Fig. 1. As can be observed, the relationship between ages and number of lights in array varied markedly as a function of gender. As a general rule, reliable differences among light conditions remained constant across ages for the boys (Tukey criterion = 1.08) but not for the girls. For the girls, reliable differences among number of lights occurred generally for the 4- and 7-yr.-olds, but not the 5- and 6-yr.-olds (with the exception of the 3-light condition).

DISCUSSION

While significant main effects were observed for age of child, number of lights in array, and presence of an interpolated space in array, these effects can only be interpreted in terms of their interactions with other variables. From the first-order interactions it can be concluded that number of lights in array is an important discriminating variable here. Task difficulty, interpreted in terms of response time, increased systematically as the number of lights in the array increased. An apparent deviation from this observation occurred with the 5- and 6-yr.-old girls (Fig. 1). Girls in these age categories responded to the 7- and 9-light conditions much faster than expected. This was especially true for the 6-yr.-old girls. One possible explanation for this could be that this group of four girls could be chronologically closer to age seven (84 months) than to being at the mid-point (77.5 mo.) of the age six category. An inspection of ages, however, showed that this was not the case. In fact, this group of girls were actually a little younger (relatively speaking) than their peers in the other three age groups. Another possible explanation could be that this group of subjects were more like 7-yr.-olds than 6-yr.-olds from the perspective of cognitive and biological development.

Referring to Fig. 1, it is apparent that age is a discriminating factor in this experiment. For the boys, a trend to decrease response time as age increases is apparent. However, this trend is somewhat distorted for the girls. In fact, the relationship between age and response time for the 7- and 9-Eight conditions is clearly quadratic in nature. This is easily verified through mean comparisons using the Tukey criterion of 1.08.

The presence of an interpolated space in the light array clearly had the effect of increasing response time regardless of position of the array. Increasing the number of lights in an array and placing an interpolated space in the array made the discrimination problem more difficult for the children.

Time to respond to a middleness problem decreased significantly as function of increased age and increased as a function of number of lights in an array. In addition, greater response latencies were observed for asymmetrical than for symmetrical arrays. These findings are consistent with those reported by Rohles (1971). Rohles, however, concluded that *different* cognitive processes were used for shorter than for longer arrays. This is a difficult conclusion to derive since the linear nature of increases in response time may actually point to increased time requirements needed to complete the *same* kind of processing task. Because we did not question the children relative to strategies used, we cannot make definitive statements about cognitive processes used. At this point it is not possible to state whether children directly perceived, the middle point in some arrays (Gibson, 1977) or whether they relied on more complex cognitive transformational skills (like counting or reasoning). The answer to this question must await further study.

An increase in the number of lights in an array increased task difficulty and response time, whereas manipulating the position of the array on the display board (left, center, right) had no such effect. It was no more difficult for a child to select the middle object when it was left or right of the body than when directly in front of the body. As with increasing the number of lights in an array, placing an interpolated space in the array had a significant effect upon response time. Regardless of subjects' ages, children took longer to respond correctly to an asymmetrical array than a symmetrical one. Consistent with Rohles (Rohles, 19 7 1; Rohles & Devine, 1966, 1967), introducing asymmetry into a middleness problem increased response latency.

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Accepted October 5, 1993.